EGYPTIAN DENTAL JOURNAL

VOL. 62, 5055:5062, OCTOBER, 2016

I.S.S.N 0070-9484

WWW.EDA-EGYPT.ORG

RETENTIVE FORCE AND SURFACE ROUGHNESS OF PARTIAL REMOVABLE FRAMEWORKS FABRICATED FROM CONVENTIONAL CHROME-COBALT AND CAD / CAM MODIFIED POLY-ETHER-ETHER-KETONE MATERIALS (WITHIN-SUBJECT EVALUATION)

Nesreen El Mekawy* *and* El Sayed Gad**

ABSTRACT

A modified poly-ether-ether-ketone (PEEK) known as BioHPP is used as an alternative material for the fabrication of distal extension RDP frameworks. It can be used for patients allergic to metals, dislike the metallic taste, the weight, and the unpleasant metal display of the framework and retentive clasps. BioHPP can be constructed either via CAD/CAM system or via the conventional lost wax technique.

Purpose: To evaluate the retentive fore and surface roughness of removable partial dentures (RPDs) constructed as conventional cobalt chromium (Co-Cr) frameworks by lost wax technique in comparison to the modified poly-ether-ether ketone (PEEK) which is termed BioHPP (Biocompatible High Performance Polymer) RPDs frameworks fabricated by Computer aided design and computer aided manufacture system (CAD/CAM): within-subject evaluation study.

Materials and Methods: Twelve patients were enrolled in this study. For all patients, two different removable partial dentures RPD frameworks were constructed; one conventional Co-Cr RPD frameworks and the other was CAD/CAM fabricated modified PEEK (BioHPP). For each framework, the force of retention was evaluated by digital forcemeter and surface roughness was evaluated by digital profilometer.

Results: There was a significant difference of retention values between the conventional Co-Cr RPDs and RPDs fabricated of Modified PEEK (BioHPP). In addition, the surface roughness evaluation demonstrates significant difference between both RPDs frameworks.

Conclusion: Under the present conditions, modified PEEK (BioHPP) should probably be considered as an alternative RPD framework material.

KEYWORDS: Retention, Roughness**,** RPDs, CAD/CAM, Co-Cr frameworks, Modified PEEK BioHPP**.**

* Assistant Professor of Removable Prosthodontics, Faculty of Dentistry, Mansoura University, Egypt

** Assistant Professor of Dental Biomaterial, Faculty of Dentistry, Mansoura University, Egypt

INTRODUCTION

Some problems are associated with the conventional removable dental prostheses (RDP) with chrome cobalt frameworks and clasps, such esthetically unacceptable display of metal clasps [1]. Newly, growing request on aesthetic pleasurable dental curative has led to prevalent use of non-metal clasp dentures (NMCDs) [2, 3] and introduction of numbers of materials used as NMCDs, which are mainly polyester or polycarbonate injection-molded thermoplastic denture base resins and polyamide [4]. It was concluded that the thermoplastic material that has a low elastic modulus is easily to manipulate. Also, it is more workable for larger retentive undercuts to improve retention than is the case with acrylic resin and metallic (Co-Cr) clasp design. However, all the manufacturers of thermoplastic materials and laboratories those making non-metal clasp dentures are still recommend the conventional Co-Cr denture design [5].

A substitutive material; poly-ether-ether-ketone (PEEK) has become broadly settled in medical engineering and it has increasingly been suggested for dental applications. A modified PEEK (BioHPP) restorative material containing 20% ceramic fillers is a high performance polymer (BioHPP; Bredent GmbH, Senden, Germany), which offers good mechanical properties, high biocompatibility, chemical stability and high temperature resistance. Moreover, the white color of BioHPP frameworks supplies a diverse esthetic procedure than the traditional metal framework display does [6]. It was concluded that, the expected retentive force of the innovative clasp design made of PEEK at different depths of tooth undercut would be compared to the conventional Co-Cr clasp design [7].

The BioHPP RDP frameworks are either constructed with the conventional lost wax technique using a vacuum press device especially designed for this material or with using computer-aided design and computer-aided manufacture (CAD/CAM) systems [8]. A major advantage of a CAD/CAM fabricated BioHPP framework is that the mechanical properties of BioHPP material are not adversely affected by the milling process as some materials can be. Modified PEEK (BioHPP) exhibits a perfect balance of the properties desirable to frameworks and can be milled very easily [9]. The advantages of such a process over conventional laboratory techniques can be concise as elimination of inter-operator variation, inherent repeatability and reduced manufacture time. In addition, frameworks are appropriately finished with minimal porosity [10, 11].

Surface smoothness of a partial removable dental prosthesis (PRDP) is substantial in banning the confinement of pathogenic microorganisms that ultimately lead to increase the incidence of oral disease and the acceleration of bio-corrosion [12]. Moreover, surface heterogeneities integrate with the cyclic nature of insertion and removal of the device may lead to PRDP_frameworks_fatigue failure [13].

To date, no systematic reviews or clinical studies focusing on the removable dentures made of modified PEEK (BioHPP) especially CAD / CAM fabricated BioHPP frameworks. Attributable to the predominant mechanical and biological properties of modified PEEK (BioHPP) [14], the goal of this study was to evaluate the retentive force and surface roughness of the RPDs fabricated from modified PEEK (BioHPP) by CAD/CAM system in comparison to the conventional Co-Cr RPDs: within-subject evaluation study.

MATERIALS AND METHODS

Patient selection

Twelve patients were enrolled in this study from the outpatient department who notify with the complaint of missing lower posterior teeth.

In which; patients fulfilled the study's inclusion standards such as mandibular bilateral distal extension, the remaining teeth extending from the first premolar on one side to first premolar on the other side, the abutments were periodontal health with no mobility, their crown/root ratio were not less than 1:1, distance between the gingival margin of the remaining natural teeth and the functional depth of the floor of the mouth was not less than 8 mm. All patients signed an informed consent form about the purpose, risks and benefits of the research. The study was conducted according to the principles of the Helsinki Declaration (2013 version).

Procedures of RPDs construction

For all patients, periodontal treatments were done. Maxillary and mandibular preliminary impressions were made to produce diagnostic models. The mandibular diagnostic models were surveyed to draw the survey line and measure the depth of retentive undercut used for the design of R P D which was chosen with a hypothetical strategy of stress-releasing design that achieve retention, support, reciprocation, bracing and connection. It was composed of a lingual bar extended from right to left mandibular first premolar to connect the bilateral meshwork minor connector. In this study; the clasp used was RPA; thus a mesial occlusal rest was prepared within the abutment and 1 mm distal guiding plane was prepared on the abutment distal surface to be connected with the proximal plate which carries the modified Aker retentive clasp arm to engage mesial retentive undercuts of first premolars. Additional rests were added on the lower canines to act as indirect retainers. Maxillary and mandibular secondary impression was made by medium body elastomeric impression; maxillary impression was poured with hard stone to produce the master model, while the mandibular impression was poured twice to form two master models for construction of both types of RPD frameworks.

Conventional RPD frameworks fabrication

Mandibular master cast undesirable undercut was block out by wax. The distal half of the facial surface of the first premolar was blocked out for R P A clasp design. The modified master cast was duplicated, then the wax pattern was fabricated, invested, burned out, and casted with chromium cobalt alloy. The metallic RPD frameworks were tried in the patient mouth, jaw relation was registered, and the upper and lower casts were mounted on a semi-adjustable articulator using maxillary face bow for upper cast and centric interocclusal record for lower one. Artificial teeth were arranged and the mandibular Kennedy Class I RPDs were tried in and processed with heat-cured acrylic resin.

Modified PEEK (BioHPP) RPD frameworks fabrication

The Mandibular master cast was fastened on table of the scanner and scanned by desktop structured-light 3D scanner (Shera-Eco Scan 7, SHERA Werkstoff-Technologie GmbH & Co. KG, Germany) to produce the 3D model.

Imported of the 3D model, this was followed by selection of the lateral view to see the model side to select the path of insertion and the 3D model tilted in the sagittal plane. Then, the model was switched to top view to make the model undercut areas invisible. All the undercut areas were selected, red highlighted, and the entire areas selected were flattening to be free of undercuts except the small areas of retentive undercut on the buccal surface of the abutment teeth used for clasp. Creation of relief was done by lifting the mesh-retainer part 0.5mm towards occlusal direction. RPD components were the same as in the conventional frameworks and created by using a pen-tablet as an input device to facilitate designing process. Then, the surface components were converted into a solid volume (Fig. 1). The sharp angles were then smoothed

at peripheries while keeping the framework configuration using smoothing tools. 3D printing of the framework was done by 5-axis milling machine with new optimized CAM software (SHERA Eco-Mill 5x, SHERA Werkstoff-Technologie GmbH & Co. KG, Germany) to mill the BioHPP directly to the desired framework design . The framework was tried in the patient mouth (Fig. 2). Jaw relation was registered; the upper and lower casts were mounted on a semi-adjustable articulator using maxillary face bow for upper cast and centric interocclusal record for lower one. Artificial teeth were arranged. Mandibular Kennedy Class I RPDs were tried in and processed with heat-cured acrylic resin.

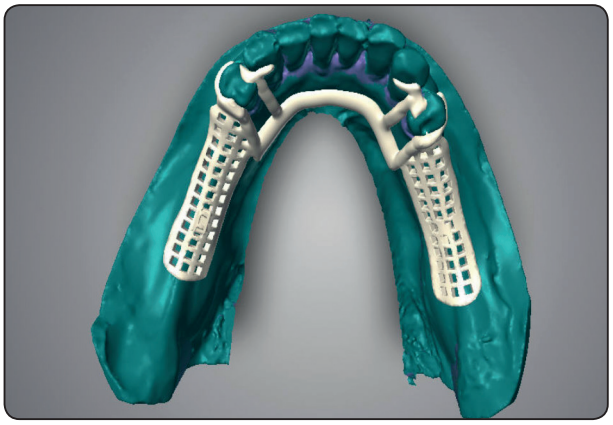

Fig. (1) 3D model and the framework configuration.

Retentive Force evaluation

Retentive force evaluation of both R P Ds were measured in the same patient after 24 hours from insertion date by using a digital forcemeter (Mecmesin Corp, Virginia, USA) device as following: The patient was seated in an upright position with the head resting. Thus, the digital forcemeter device could apply a vertical dislodging force on the R P D, the device was used so that its pull end was engaging the center of an 0.9 mm orthodontic wire that attached to two hooks one on each side of the buccal surface of the framework between second premolar and first molar teeth, then pulled vertically (Fig. 3) until the denture was elevated [15, 16]. This force was measured in newton and recorded as the R P D retention. For each patient, the average of three records was taken for each RPD.

Fig. (2) BioHPP framework seated in the patient mouth.

Surface roughness evaluation

Before fitting of both R P Ds frameworks in the patient mouth, evaluation of surface roughness was done by using a profilometer (Fig.4) (Mitutoyo SJ-201, USA) with a diamond stylus has tip radius of 5 um. The measuring force is 4 mN with a measuring speed of 0.5 mm/s, while the cutoff value was set at 0.8 mm [12]. Surface roughness calculation was

Fig. (3) Retention force measuring of Co-Cr RPD using digital forcemeter.

Fig. (4) Surface roughness measuring of BioHPP framework using profilometer

performed by using the mean of 3 measurements recorded from the lingual major connector along the following 3 sites: the center along the midline, 1 mm to the right and parallel to the midline, and 1 mm to the left and parallel to the midline. Each site was measured 5 times, and an average was calculated.

Statistical Analysis

The SPSS statistical package for social science version 22 (SPSS Inc., Chicago, IL, USA) was used for data analysis. Shapiro-Wilk test was used to test the normality of the recoded values. The data was parametric and normally distributed. Multivariate analysis with repeated measures (ANOVA) was applied to test possible differences between groups**.** Paired samples t-test was used. P is significant if <0.05 at confidence interval 95%.

RESULTS

Table 1 demonstrates Paired t-test for comparing the values of retention of RDPs frameworks constructed from either chromium cobalt alloy or from BioHPP. It was found that there is a statistically significant (P = 0.0001) difference between retention values of both frameworks. RDPs constructed from chromium cobalt alloy recorded higher mean of retention values (2.294 ± 0.668) than the retention values of frameworks constructed from modified PEEK (BioHPP) (1.069 ± 0.353).

TABLE (1) Comparing retention values (mean+_SD) of Co-Cr and BioHPP RPDs

	Mean (N)	± SD	T value	P value
Co-Cr	2.294	± 0.668	9.73	0.0001*
BioHPP	1.069	± 0.353		

Table 2 shows Paired t-test for comparing surface roughness of RDPs frameworks constructed from either chromium cobalt alloy or from modified PEEK (BioHPP). It was found that there is a statistically significant (P = 0.0001) difference between surface roughness of both frameworks. Modified PEEK (BioHPP) frameworks recorded higher surface roughness (0.863 ± 0.162) than the surface roughness of frameworks constructed from chromium cobalt alloy (0.580 **±** 0.139**).**

TABLE (2) Comparing surface roughness values (mean±SD) of Co-Cr and BioHPP RPD frameworks

	Mean (μm)	± SD	T value	P value
Co-Cr	0.580	± 0.139	10.67	0.0001*
BioHPP	0.863	± 0.162		

DISCUSSION

This study was designed to evaluate the retention and surface roughness of conventionally manufactured chrome cobalt frameworks and CAD/CAM manufactured modified PEEK (BioHPP; high performance polymer) used for fabrication of the R P Ds frameworks. The choice of the material for the construction of RDPs should be based on clinical examination, patient's demands, and scientific evidence. Traditional chrome cobalt frameworks RDPs do not always comply with the patient's esthetic demands, hence a metal-free appliances renewed.

A modified PEEK (BioHPP) in conjunction with regular acrylic artificial teeth and commonplace heat-cured denture base acrylic resin was used as an alternative RDP framework material. Due to its white color and high strength, it exhibits a perfect balance of the properties desirable to frameworks, lightweight for improved patient comfort, no thermal or electrical conductivity, non-allergenic, and metal-free denture framework is a taste neutral (no metal taste). In addition, shock absorbent during chewing and have high resistance to abrasion and decay. Thus, BioHPP permits the fabrication of metal-free clasp, occlusal rests, providing occlusal stability and metal-free esthetics [9,17].

The framework of a Kennedy class I often cause torqueing of the abutment teeth and traumatization of edentulous mucosa due to the different viscoelasticity of the edentulous ridges and the periodontal ligaments. BioHPP framework had the beneficial for the periodontal health of the abutment teeth; as its elasticity might reduce the stress on the abutment teeth and the distal torque. Hence, it could be hypothesized that BioHPP frameworks would be an applicable alternate for diminished periodontal support abutments when managing Kennedy class I [17].

For RDP patient wearers, retention plays a vital function. In this study, the impact of framework materials on the retention forces was examined; it showed a significant impact on retentive force values. BioHPP RDP framework demonstrates reduced retention force than that of chrome cobalt RDP frameworks which is a matter of concern. This can be attributed to the BioHPP flexibility and the use of a shallow undercuts equal 0.25 mm which is the most routinely used depth of undercut for Co Cr clasps; as the Co Cr clasps are stiffer in nature, so it is difficult to use these alloy clasps for larger undercuts as this is within-subject evaluation and both RDP frameworks were used for the same patients. This in agreement with Tannous et al., [18] whom stated that PEEK clasps offer a lower retentive force than metal clasps. However, correctly designed modified PEEK (BioHPP) clasps with an undercut of 0.5 mm would provide sufficient retention values. In addition, the weight may play a role in reducing the retention force values of modified PEEK; as BioHPP has low specific weights which allow the fabrication of lighter RDP than the metallic RDP, where BioHPP RDP weighed 27.5% less than its Co-Cr predecessor [17,19].

Surface roughness has participated role in accumulation of plaque, microorganisms retention, and a menace to the supporting structures health [12]. Ra equal to 0.2 um were considered as the surface roughness threshold for dental plaque retention. The surface roughness is still an important aspect since it directly or indirectly affects wear resistance, patient comfort, periodontal health, and surface color [20]. In this study, frameworks constructed from modified PEEK (BioHPP) recorded higher surface roughness than that of frameworks constructed from chromium cobalt alloy; this may be attributed to the presence of the ceramics fillers within the surface of the frameworks as a result of the milling process, leading to their surface roughness. While, the surface roughness of the frameworks constructed from chromium cobalt alloy was minimized due to the electro-polishing procedure of the frameworks. This result is controversial with in vitro tests by the University of Jena [21]; these tests showed that BioHPP can be polished to Ra values of 0.018 μm

following a strict polishing protocol. The difference between our results and the results of tests performed by University of Jena is that they used pressable type of BioHPP which its frameworks were constructed by the conventional lost wax technique and heat press not by CAD/CAM system. In the same moment, the abrasiveness of modified PEEK (BioHPP) is excellent against the natural teeth. Despite of low elastic moduli and abrasive resistance of modified PEEK (BioHPP), but it is competitive with metallic alloys [22]. In regard to the surface roughness values obtained of CAD/CAM fabricated BioHPP frameworks in our study, there is an expectation of good polishability and adequate roughness if these frameworks were polished under an authoritarian protocol.

The above distal extension RDP presents a short-term clinical follow-up, submitting no framework fracture and good clasp retention. There has been no sign of change in the BioHPP framework, in conformity with the literature [23]. No previous studies were performed on CAD/CAM fabricated modified PEEK (BioHPP) RPDs. Short term recall appointments are needed to record clinical status with reliable follow up.

CONCLUSION

Under the present conditions, BioHPP RDPs showed higher surface roughness values and lower retention values than Co-Cr RDPs. BioHPP should probably be considered as an alternative RDP framework material. Further long term clinical evidence is needed to consolidate the scientific data.

REFERENCES

1. Behr M, Zeman F, Passauer T, Koller M, Hahnel S, Buergers R, Lang R, Handel G, Kolbeck C. Clinical performance of cast clasp-retained removable partial dentures: a retrospective study. Int J Prosthodont 2012;25:138-44.
2. Iwata Y. Assessment of clasp design and flexural properties of acrylic denture base materials for use in nonmetal clasp dentures. J Prosthodont Res 2016; 60:114-22.
3. Fueki K, Ohkubo C, Yatabe M, Arakawa I, Arita M, Ino S, et al. Clinical application of removable partial dentures using thermoplastic resin – Part I: definition and indication of nonmetal clasp dentures. J Prosthodont Res 2014;58:3–10.
4. Wada J, Fueki K, Yatabe M, Takahashi H, Wakabayashi N. A comparison of the fitting accuracy of thermoplastic denture base resins used in non-metal clasp dentures to a conventional heat cured acrylic resin. Acta Odontol Scand 2015;73:33–7.
5. Alwan S, Ismail I. Retentive forces, tensile strength and deflection fatigue of Acetal thermoplastic clasp material in comparison with cobalt-chromium alloy. J Bagh Coll Dentistry 2014;26: 59-66.
6. Siewert B, Parra M. A new group of material in dentistry. Peek as a framework material used in 12-piece implant-supported bridges. Z Zahnarzt Implantol 2013;29:148-59.
7. Muhsin S, Hatton P, Johnson A, Sereno N, Wood D. Retentive Force of Novel Polyetheretherketone Clasp Design. Poster presented at 3rdMeeting of the IADR Asia Pacific Region; 35th Annual Meeting of the IADR Korean Division. 2016, June.
8. Kurtz SM, Devine JN. PEEK biomaterials in trauma, orthopedic, and spinal implants. Biomaterials 2007;28:4845–69.
9. Whitty T. PEEK- A new material for CAD/CAM dentistry. eLABORATE 2014; March/April:32-36 .
10. Jevremović D, Kojić V, Bogdanović G, Puškar T, Eggbeer D, Thomas D, Williams R. A selective laser melted Co–Cr alloy used for the rapid manufacture of removable partial denture frameworks – initial screening of biocompatibility. J Serb Chem Soc 2011;76 (1): 43–52.
11. Williams RJ, Eggbeer D, Bibb R. CAD/CAM Rapid Manufacturing Techniques in the Fabrication of Removable Partial Denture Frameworks, Quintessence J. Dental Technol 2008; 6(1): 42-50.
12. Swelem AA, Abdelnabi MH, Al-Dharrab AA, AbdelMaguid HF. Surface roughness and internal porosity of partial removable dental prosthesis frameworks fabricated from conventional wax and light-polymerized patterns: A comparative study. J Prosthet Dent 2014;111(4):335-41.
13. Zavanelli RA, Pessanna Henriques GE, Ferreira I, De Almeida Rollo JM. Corrosion fatigue life of commercially pure titanium and Ti-6Al-4V alloys in different storage environments. J Prosthet Dent 2000;84:274-9.

14. Najeeb S, Zafar MS, Khurshid Z, Siddiqui F. Applications of polyetheretherketone (PEEK) in oral implantology and prosthodontics. J Prosthodont Res 2016;60(1):12-9.

15. Burns DR, Unger JW, Coffey JP, Waldrop TC, Elswick RK Jr. Randomized, prospective, clinical evaluation of prosthodontics modalities for mandibular implant overdenture treatment. J Prosthet Dent 2011; 106: 12-22.

16. EL Mekawy N, Hegazy S, Raouf C. Impact of Denture Base Materials on Retention of Tooth Retained and Supported Mandibular Overdenture. Periodon Prosthodon 2015; 1 :1.

17. Zoidis P, Papathanasiou I, Polyzois G. The Use of a Modified Poly-Ether-Ether-Ketone (PEEK) as an Alternative Framework Material for Removable Dental Prostheses: A Clinical Report. J Prosthodont 2016;25(7):580-4.

18. Tannous F, Steiner M, Shahin R, Kern M. Retentive forces and fatigue resistance of thermoplastic resin clasps. Dent Mater 2012;28:273-8.

19. Fueki K, Ohkubo C, Yatabe M, et al: Clinical application of removable partial dentures using thermoplastic resin-Part II: material properties and clinical features of non-metal clasp dentures. J Prosthodont Res 2014;58:71-84.

20. Bollen, ML, Lambrechts, P, Quirynen, M. Comparison of surface roughness of oral hard materials to the threshold surface roughness for bacterial plaque retention: A review of the literature. Dent Mater 1997; 13: 258-69.

21. Rzanny A, Gobel F, Fachet M. BioHPP summary of results for material tests. Research Report. Jena, Germany, University of Jena, Department of Materials and Technology, 2013.

22. Zok F, Miserez A. Property maps for abrasion resistance of materials. Acta Mater 2007;55:6365–71.

23. Siewert B, Parra M. A new group of material in dentistry. Peek as a framework material used in 12-piece implant-supported bridges. Z Zahnarzt Implantol 2013;29:148-59.